International Journal of Agricultural Technology 2023 Vol. 19(4):1777-1790
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

# The effect of polyethylene glycol induced drought stress on seed germination stage and seedling growth of different soybean varieties

**Prameswari, W.[1*], Salamah, U.[1], Husna, M.[1], Pujiwati, H.[1], Simarmata, M.[1] and Aziz, I.[2]**

[1]Department of Agroecotechnology, University of Bengkulu, Bengkulu, Indonesia; [2]Student undergraduate of Agroecotechnology, University of Bengkulu, Bengkulu, Indonesia.

Prameswari, W., Salamah, U., Husna, M., Pujiwati, H. and Aziz, I. (2023). The effect of polyethylene glycol-induced drought stress on seed germination stage and seedling growth of different soybean varieties. International Journal of Agricultural Technology 19(4):1777-1790.

**Abstract** The results showed that the interaction between varietal treatment and osmotic potential significantly affected growth percentage, root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root shoot ratio, and chlorophyll index (SPAD value) both at the stage of seed germination and seedling growth. Induction of potential osmotic -0.19 MPa reduced the growth percentage by 21.93% and 33.99%, 32.04% and 41.66% at root length, and by 41.66% and 36.77% at shoot length both at seed germination and seedling growth stages, respectively. Meanwhile, the potential osmotic induction of -0.67 MPa reduced the growth percentage by 39.75% and 52.81%, by 51.68% and 61.32% in root length, and by 61.82% and 55.95% on shoot length at both seed germination and seedling growth respectively. Gepak Kuning Variety has a better tolerance for osmotic potential than the other four varieties. It can conclude that Gepak Kuning variety could be used as breeding material to develop drought-resistant soybean varieties.

**Keywords:** Abiotic stress, Crops, PEG-6000

## Introduction

Soybean (*Glycine max* (L) Merrill) is one of Indonesia's critical food crop commodities, which has economic value and used as a source of vegetable protein for the community. In addition, soybeans use as raw materials for foods such as tofu, tempeh, soy sauce, and others. *Soybean* is a commodity that needs attention because the demand for soybeans in Indonesia is relatively high. At the same time the harvest and production areas continue to wait so that soybean imports continue to increase (Endriani *et al.*, 2017). Along with population growth that continues to increase, the demand for soybeans in the community also increases, but soybean production in Indonesia is insufficient. According to data from the Central Statistics Agency (BPS) (2016), the domestic demand for

* **Corresponding Author**: Prameswari, W.; **Email**: wprameswari@unib.ac.id

soybeans is relatively high, reaching 204 million tons per year, while the national soybean production in 2016 only reached 963,183 tons. The demand for national soybean needs has also increased.

One of the efforts to overcome this soybean problem is with an agricultural extensification program, namely by expanding the soybean planting area by utilizing marginal land, including dry land. The main problem in dry land is the little water used for agricultural cultivation, so plants often experience drought stress. Drought stress is one of the environmental conditions that can affect plant growth and productivity. Drought can cause anatomical, morphological, physiological, biochemical, and molecular changes in plants. The ability of plants to adapt to drought stress depends on the intensity and period of stress, growth phase, and plant genotype (Kalefetoglu and Ekmekci, 2005). The response of plants to drought varies depending on the duration, intensity of stress, plant species, and plant growth stage (Kusvuran, 2012).

Drought stress can significantly reduce crop productivity, so drought-tolerant soybean varieties are the right solution to reduce the decline in soybean yields due to drought stress. Breeding methods and biotechnology may play an essential role in developing crop cultivars with increased tolerance to drought, and selected cultivars can use to increase agricultural production in dryland areas (Hemon and Sudarsono, 2010). The selection method for drought tolerant traits can do by planting the selected population in the target field or potting media with reduced water supply. However, this method has weaknesses, namely the uniformity of selection pressure which is difficult to maintain, and the relative water retention cannot be determined (Sugihono, 2011). In vitro, a rapid screening method can use as a solution for the selection of drought-tolerant soybean genotypes. The comparative advantage of this method is that the selection time is shorter, does not require ample space, is easy to control, and is not limited by seasons.

The seedling stage of crops plant is highly vulnerable to water deficits. The seed germination stage is a prerequisite and a critical transition stage for plants. According to Farooq *et al.* (2019), during the germination stage, wheat seeds in semiarid areas experience low water availability. Low water availability during seed germination and later plant growth stages can decrease production maturation time (Bayoumi *et al.,* 2008). The impact of drought stress on the seed germination stage and vegetative growth of each plant is different such as wheat (Rauf *et al*., 2007), maize (Farsiani and Ghobadi, 2009), and barley (Berg *et al.,* 2014; Yassin *et al.,* 2019) in previous studies.

The success of the establishment of food crops depends on the nursery's microclimate conditions and the seeds' quality (Khajeh-Hosseini *et al*., 2003). Therefore, plant seed germination was tested under a simulated environment to infer tolerance to unfavorable environmental conditions. Studies related to seed germination under Polyethylene glycol (PEG)-induced drought stress are the most commonly used screening method to test the drought tolerance of different plant varieties during seed germination and early stand formation. Polyethylene glycol (PEG) can use as a selection agent in rapid screening for drought tolerance, both in vitro (Kosmiatin *et al*., 2005) and ex Vitro (Widoretno, 2011).

Seed germination and seedling establishment are essential criteria for testing the tolerance of wheat genotypes to various abiotic stresses, especially drought stress (Hubbard *et al.,* 2012). The percentage of seed germination and seedling formation significantly reduced when the osmotic potential of the soil reached -1.5 MPa (Farooq *et al*., 2019; Me ́rida-Garcı ́a *et al*., 2019). Short-stature wheat cultivars have slower initial growth and coleoptile length, and leaf index decrease during the early growth period (Pereira *et al*., 2002). Plant breeding was concentrated on above-ground traits for a long time, whereas root traits had neglect due to some difficulties (Ehdaie *et al*., 2012). Root properties have received significant attention over the last decade (Richard *et al*., 2015). Genotyping screening for early drought tolerance and inferring root attributes at the seedling stage has shown significant progress (Chloupek *et al*., 2010).

Therefore, the objectives were determined the growth response of six soybean varieties to PEG (Polyethylene glycol)-induced drought stress during the seed germination and seedling stage and rapidly screened the potential and adaptive soybean varieties to drought stress.

## Materials and methods

The research was carried out at the *Greenhouse* of the Faculty of Agriculture, Bengkulu University. This research was conduct from February to June 2022. The plant materials used were six soybean varieties, namely Gepak Kuning, Derap 1, Dega 1, Dena 1, Dena 2, and Devon 1. The study used a completely randomized block design (RCBD) with two factors. The first factor was osmotic potentials induced by PEG 6000 of 3 levels, namely 0.0 MPa (control), -0.19 MPa, and -0.67 MPa and the second factor was soybean varieties consisting of 5 levels, namely Gepak Kuning, Derap 1, Dega 1, Dena 1, Dena 2, and Devon 1. The observational data were analyzed using the F test. If the treatment showed a significant effect at the 5% level, the analysis was continued with DMRT (Duncan Multiple Range Test) at the level $\alpha = 5\%$.

***Seed germination experiment***

Every three replicates of 25 sterile seeds were added with 5% sodium hypochlorite and germinated between three layers of Whatman No.1 filter paper in 150 x 15 mm Petri dishes. The treatment solution or distilled water as much as 10 ml was poured on filter paper and then given a solution or distilled water as needed. Petri dishes were covered with Parafilm to prevent evaporation. Seeds were incubated at a temperature of 23±2˚C and a light dark period of 12 hours for 12 days. The percentage of seed germination was observed every 24 hours for 12 days and then the percentage of seed germination was calculated. The seed is considered to have 'germinated' once the radicle has elongated to 1-2 cm.

***Seedling growth experiment***

Seed growth experiments was carried out in 20x20 cm polybags containing a mixture of soil and cow manure (1:1; v/v). The Polybags were placed into the growth cabinet with three replicates, and 25 seeds were planted in each replicate. Seeds were sown to a depth of 3 cm, and polybags were irrigated with PEG-6000 solution to produce an osmotic potential of 0.0 MPa (control), -0.19 MPa, and -0.67 MPa. Polybags were incubated at 25˚C, and humidity ranged from 70-80% for 21 days. Seeds are considered to emerge when the emerging radicle reaches the soil surface. Observations were made from seedlings aged seven days after planting (DAP). The observed variables were growth percentage, root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root shoot ratio, and chlorophyll index (SPAD value)—both at the stage of seed germination and seedling growth.

## Results

The effect of different soybean varieties on the germination stage induced by PEG (*Polyethylene glycol*) at different osmotic potentials showed a significant effect on the variables of seed germination percentage, root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root shoot ratio and chlorophyll index (Table 1). Gepak Kuning variety had the highest seed germination percentage of 85.78%, while the Dena 2 variety had the lowest seed germination percentage of 62.22%. However, the Dena 2 variety was not significantly different from the Dena 1 variety for the percentage of seed germination, which was 64.44%.

Each soybean variety was differes in root length and shoot length. The Gepak Kuning variety had the highest root and shoot length as compared to the other five soybean varieties. The root length and shoot length of each soybean variety were as follows: Gepak Kuning (18.64 cm and 16.43 cm), Derap 1 (16.93 cm and 14.67 cm), Dega 1 (16.12 cm and 14.06 cm). cm) Devon 1 (14.62 cm and 12.26 cm), Dena 1 (13.63 cm and 11.12 cm) and Dena 2 (12.78 cm and 10.41 cm) respectively.

**Table 1.** The Effect of different varieties on their seed germination and growth traits grown under different osmotic potentials

| Soybean Varieties | GP (%) | RL (cm) | SL (cm) | FRW (g) | DRW (g) | FSW (g) | DSW (g) | R/S | CI (SPAD Value) |
|---|---|---|---|---|---|---|---|---|---|
| **Gepak Kuning** | 85,78a | 18,64a | 16,43a | 0,94a | 0,36a | 0,83a | 0,23a | 0,428c | 34,65a |
| **Derap 1** | 76,44b | 16,93b | 14,67b | 0,85b | 0,32b | 0,74b | 0,21b | 0,433bc | 32,85b |
| **Dega 1** | 73,33c | 16,12c | 14,06c | 0,80c | 0,30c | 0,68c | 0,19c | 0,451b | 31,92c |
| **Dena 1** | 64,44d | 13,63e | 11,12e | 0,70de | 0,27de | 0,58e | 0,17de | 0,494a | 27,68e |
| **Dena 2** | 62,22d | 12,78f | 10,41f | 0,67e | 0,26e | 0,54e | 0,16e | 0,513a | 27,09e |
| **Devon 1** | 73,33c | 14,62d | 12,26d | 0,74d | 0,28d | 0,63d | 0,18d | 0,453b | 29,41d |

Note : GP = seed germination percentage, RL = root length, SL = shoot length, FRW = fresh root weight, DRW = dry root weight, FSW = fresh shoot weight, DSW = dry shoot weight, R/S = root:shoot ratio, CI = chlorophyll index. The means sharing same letters within a same column are statistically non-significant ($p > 0.05$).

However, the varieties Dena 1 and Dena 2 were not significantly differed with a root-shoot ratio of 0.494 and 0.513. Similarly, the Dega 1 variety was not significantly differed from the Devon 1 variety, which had a root-to-root ratio of 0.451 and 0.453, respectively. The Gepak Kuning variety had the lowest root-shoot ratio, which was 0.428, but it was not significantly differed from the Derap 1 variety, which had a root-shoot ratio of 0.433.

In addition, each soybean variety significantly affected the variables of fresh root weight and dry root weight. The fresh root weight and dry root weight of each variety varied greatly. The Gepak Kuning variety had the highest fresh root weight and dry root weight of 0.94 g and 0.36 g, while the Dena 2 variety had the lowest fresh root weight and dry root weight of 0.67 g and 0.26 g, respectively. The Dena 1 variety was not significantly different from the Dena 2 and Devon 1 varieties. The fresh root weight and dry root weight of the Dena 1 variety were 0.70 g and 0.27 g, respectively (Table 1).

Meanwhile, the Dena 2 and Dena 1 varieties were not significantly differed in the chlorophyll index variable. They had the smallest chlorophyll index values of 27.09 and 27.68, respectively, while the Gepak Kuning variety had the highest chlorophyll index value of 34.65. Based on table 1, it can conclude that the Gepak Kuning variety has better drought stress tolerance compared to the other five varieties. Meanwhile, Dena 2 variety has the lowest tolerance level to drought stress when compared to the other five soybean varieties. This can see in the response of soybean plant growth to drought stress at the seed germination stage.

**Table 2.** The Effects of different osmotic potentials on seed germination and growth traits of different soybean varieties included in the study

| Osmotic Potential | GP (%) | RL (cm) | SL (cm) | FRW (g) | DRW (g) | FSW (g) | DSW (g) | R/S | CI (SPAD Value) |
|---|---|---|---|---|---|---|---|---|---|
| **0.0 MPa** | 92,22a | 21,44a | 20,09a | 1,17a | 0,47a | 1,04a | 0,33a | 0,452b | 38,37a |
| **-0.19 MPa** | 70,00b | 14,57b | 11,72b | 0,68b | 0,26b | 0,57b | 0,16b | 0,463ab | 29,16b |
| **-0.67 MPa** | 55,56c | 10,36c | 7,67c | 0,50c | 0,18c | 0,40c | 0,08c | 0,472a | 24,27c |

Note : GP = seed germination percentage, RL = root length, SL = shoot length, FRW = fresh root weight, DRW = dry root weight, FSW = fresh shoot weight, DSW = dry shoot weight, R/S = root:shoot ratio, CI = chlorophyll index. The means sharing same letters within a same column are statistically non-significant ($p > 0.05$).

Different osmotic potential at the seed germination stage significantly affected all observed variables such as seed germination percentage, root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root-shoot ratio, and chlorophyll index value (Table 2). Osmotic potential of -0.19 MPa showed the percentage of seed germination percentage, root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root-shoot ratio, and the highest chlorophyll index value when compared to the osmotic potential of -0.67 MPa. However, the -0.67 MPa osmotic potential had a higher root-shoot ratio when compared to the -0.19 MPa and 0.0 MPa osmotic potential (control). The percentage of seed germination decreased by 21,93% (-0.19 MPa) and 39,75% (-0.67 MPa) when compared with the potential osmotic treatment of 0.0 MPa (control). Meanwhile, the root length variable also decreased by 32,04% (-0.19 MPa) and 51,68% (-0.67 MPa) when compared to the potential osmotic treatment of 0.0 MPa (control).

The effect of different soybean varieties significantly affected growth percentage, root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root shoot ratio, and chlorophyll index value (Table 3). Gepak Kuning variety has better performance and growth characteristics when compared to the other five varieties. The highest growth percentage at the nursery stage obtain by the Gepak Kuning variety with a value of 78.67%, followed by the Derap 1 variety at 70.67%, Dega 1 at 68.44%, Devon 1 at 61.33%, Dena 1 at 56.44%, and Dena 2 52.00%. Meanwhile, the root length and shoot length of the six soybean varieties varied greatly. Gepak Kuning variety had the highest root length and shoot length of 16.43 cm and 19.39 cm, while the Dena 2 variety had the lowest root length and shoot length of 10.62 cm 13.16 cm, respectively.

**Table 3.** The Effects of different varieties on percentage decrease in their seedling and growth traits under different osmotic potentials

| Soybean Varieties | GP (%) | RL (cm) | SL (cm) | FRW (g) | DRW (g) | FSW (g) | DSW (g) | R/S | CI (SPAD Value) |
|---|---|---|---|---|---|---|---|---|---|
| **Gepak Kuning** | 78,67a | 16,43a | 19,39a | 2,65a | 0,68a | 4,03a | 1,08a | 0,63ab | 35,97a |
| **Derap 1** | 70,67b | 14,67b | 17,53b | 2,46b | 0,63b | 3,84b | 1,04b | 0,61b | 33,76b |
| **Dega 1** | 68,44b | 14,06c | 16,86c | 2,41b | 0,62b | 3,65c | 0,99c | 0,64a | 32,19c |
| **Dena 1** | 56,44d | 11,12e | 13,67e | 2,21d | 0,58d | 3,41d | 0,94d | 0,62ab | 28,02e |
| **Dena 2** | 52,00e | 10,62f | 13,16f | 2,09e | 0,55e | 3,17e | 0,88e | 0,63ab | 26,65f |
| **Devon 1** | 61,33c | 12,26d | 15,13d | 2,31c | 0,60c | 3,44d | 0,95d | 0,65a | 29,58d |

Note : GP = seedling percentage, RL = root length, SL = shoot length, FRW = fresh root weight, DRW = dry root weight, FSW = fresh shoot weight, DSW = dry shoot weight, R/S = root:shoot ratio, CI = chlorophyll index. The means sharing same letters within a same column are statistically non-significant ($p > 0.05$).

In contrast to the other variables, the variable root shoot ratio showed that the Devon 1 variety had the highest root shoot ratio of 0.65, while the Derap 1 variety had the lowest root shoot ratio of 0.61. Meanwhile, the varieties of Gepak Kuning, Dena 1, and Dena 2 showed no significant difference for the root shoot ratio variable, 0.63, 0.62, and 0.63, respectively. For the chlorophyll index variable, Dena 2 variety has the lowest index value of 26.65 compared to the other five soybean varieties (Table 3).

Different osmotic potential at the seedling stage significantly affected all observed variables such as seed germination percentage, root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root-shoot ratio, and chlorophyll index value. (Table 4). Osmotic potential of -0.19 MPa showed the percentage of seed germination percentage, root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root-shoot ratio, and the highest chlorophyll index value when compared to the osmotic potential of -0.67 Mpa. However, the -0.67 MPa osmotic potential had a higher root-shoot ratio when compared to the -0.19 MPa and 0.0 MPa osmotic potential (control). The percentage of seed germination decreased by 33,99% (-0.19 MPa) and 52,81% (-0.67 MPa) when compared with the potential osmotic treatment of 0.0 MPa (control). Meanwhile, the root length variable also decreased by 41,66% (-0.19 MPa) and 61,32% (-0.67 MPa) when compared to the potential osmotic treatment of 0.0 MPa (control).

The potential osmotic potential pressure also affects the growth of shoot length. The potential osmotic pressure of -0.19 MPa decreased by 36.77% compared to the potential osmotic pressure of 0.0 MPa (control), while the osmotic potential of -0.67 MPa decreased the shootlength by 55.95% (Table 4). It can conclude that the higher the osmotic potential pressure (drought stress), it will inhibit plant growth.

The results of the analysis showed that there was an interaction between soybean varieties and drought stress (induced by PEG 6000) on all observed variables, namely root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, root shoot ratio, and the value of chlorophyll index (Table 5; Figures 1 and 2). Drought stress ranging from -01.9 MPa to -0.67 MPa provided different growth responses for each soybean variety. When the condition was -0.67 Mpa, the Gepak Kuning variety showed a better growth response and tolerance level to drought stress when compared to the other five soybean varieties under the same stress conditions. Meanwhile, the Dena 2 variety under drought stress conditions of -0.67 MPa showed a lower growth response and tolerance level when compared to the other five soybean varieties.

The root shoot ratio variable showed that the Dena 2 variety had the smallest root ratio of 0.70. In contrast, the Gepak Kuning variety had the highest root ratio of 0.85 under drought stress conditions of -0.19 MPa. Meanwhile, the root shoot ratio variable showed that Devon 1 and Dena 1 varieties had the smallest root shoot ratio of 0.71. In contrast, the Gepak Kuning variety had the highest root ratio of 0.81 under drought stress conditions -0.67 MPa (Table 5).

**Table 4.** The Effects of different osmotic potentials on seedling and growth traits of different soybean varieties included in the study

| Osmotic Potential | GP (%) | RL (cm) | SL (cm) | FRW (g) | DRW (g) | FSW (g) | DSW (g) | R/S | CI (SPAD Value) |
|---|---|---|---|---|---|---|---|---|---|
| **0.0 MPa** | 90,89a | 20,09a | 23,09a | 2,85a | 0,86a | 4,24a | 1,36a | 0,63a | 38,97a |
| **0.19 MPa** | 60,00b | 11,72b | 14,60b | 2,22b | 0,58b | 3,43b | 0,96b | 0,60b | 29,33b |
| **0.67 MPa** | 42,89c | 7,77c | 10,17c | 2,00c | 0,40c | 3,11c | 0,62c | 0,65a | 24,78c |

Note : GP = seedling percentage, RL = root length, SL = shoot length, FRW = fresh root weight, DRW = dry root weight, FSW = fresh shoot weight, DSW = dry shoot weight, R/S = root:shoot ratio, CI = chlorophyll index. The means sharing same letters within a same column are statistically non-significant (p > 0.05).

**Table 5.** The Effects of soybean varieties by different osmotic potentials' interaction on decrease in seedling and growth traits of soybean varieties

| Combination treatment | FRW (g) | DRW (g) | FSW (g) | DSW (g) | R/S | CI (SPAD Value) |
|---|---|---|---|---|---|---|
| **G1D1** | 2,87a | 0,86a | 4,24a | 1,36a | 0,87a | 39,03a |
| **G1D2** | 2,70b | 0,70b | 4,02b | 1,13ab | 0,85ab | 36,00b |
| **G1D3** | 2,37c | 0,47d | 3,82d | 0,76cd | 0,81b | 32,87d |
| **G2D1** | 2,84a | 0,85a | 4,23a | 1,35a | 0,87a | 38,97a |
| **G2D2** | 2,41c | 0,62c | 3,74c | 1,05b | 0,83ab | 33,41c |
| **G2D3** | 2,15de | 0,43de | 3,56e | 0,71cd | 0,79bc | 28,91e |
| **G3D1** | 2,83a | 0,85a | 4,24a | 1,36a | 0,87a | 38,94a |
| **G3D2** | 2,29c | 0,60c | 3,52d | 0,98b | 0,83ab | 30,69d |
| **G3D3** | 2,10fg | 0,42e | 3,19f | 0,64d | 0,77c | 26,93f |
| **G4D1** | 2,85a | 0,85a | 4,24a | 1,36a | 0,87a | 38,99a |
| **G4D2** | 1,98ef | 0,52cd | 3,19f | 0,90bc | 0,77c | 25,19g |
| **G4D3** | 1,81i | 0,36g | 2,79g | 0,56e | 0,71d | 19,88i |
| **G5D1** | 2,84a | 0,85a | 4,23a | 1,35a | 0,87a | 38,97a |
| **G5D2** | 1,83g | 0,47d | 2,85g | 0,80c | 0,70d | 23,50g |
| **G5D3** | 1,61j | 0,32f | 2,44i | 0,49f | 0,75cd | 17,48j |
| **G6D1** | 2,85a | 0,86a | 4,23a | 1,36a | 0,87a | 38,92a |
| **G6D2** | 2,12d | 0,55cd | 3,22ef | 0,90bc | 0,78c | 27,19ef |
| **G6D3** | 1,96h | 0,39ef | 2,88h | 0,58e | 0,71d | 22,62h |

Note : G1 = Gepak Kuning, G2 = Derap 1, G3 = Dega 1, G4 = Dena 1, G5 = Dena 2, G6 = Devon 1, D1 = 0.0 MPa, D2 = -0.19 MPa, and D3 = -0.67 MPa. FRW = fresh root weight, DRW = dry root weight, FSW = fresh shoot weight, DSW = dry shoot weight, R/S = root:shoot ratio, CI = chlorophyll index. The means sharing same letters within a same column are statistically non-significant (p > 0.05).

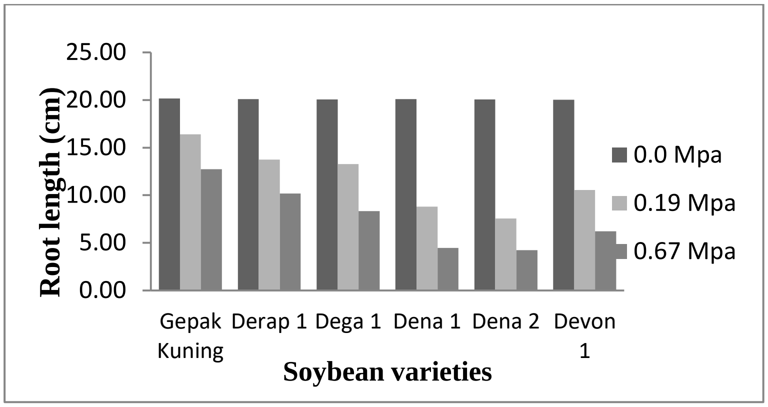


**Figure 1.** Root length (RL) of six varieties under control and drought stress

The highest decrease in root length (RL) was in the Dena 2 variety, which was 62.28% (-0.19 MPa) and 78.92% (-0.67 MPa). Meanwhile, the smallest decrease in root length in the Gepak variety was 18.69% (-0.19 MPa) and 36.89% (-0.67 MPa). Then followed by Derap 1 (31.69% and 49.40%), Dega 1 (33.88% and 58.50%), Devon 1 (47.43% and 69.05%), and Dena 1 ( 56.23% and 77.76%) under drought stress conditions of -0.19 MPa and -0.67 Mpa, respectively (Figure 1).

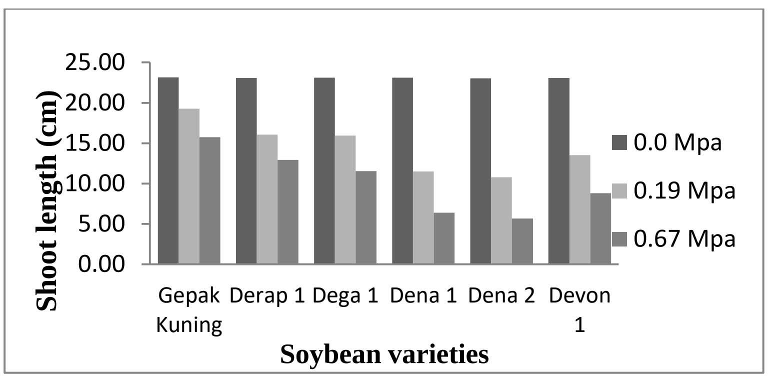


**Figure 2**. Root length (RL) of six varieties under control and drought stress

In addition to root length, a decrease occurred in the variable shoot length (SL). The highest decrease in shoot length was in the Dena 2 variety, namely 53.23% (-0.19 MPa) and 75.38% (-0.67 MPa). Meanwhile, the smallest decrease in shoot length in the Gepak variety was 16.83% (-0.19 MPa) and 32.11% (-0.67 MPa). Then followed by varieties Derap 1 (30.39% and 43.95%), Dega 1 (31.04% and 50.09%), Devon 1 (41.35% and 61.86%), and Dena 1 (50.28% and 72.46%) under drought stress conditions of -0.19 MPa and -0.67 MPa, respectively (Figure 2).

## Discussion

Each soybean tested had a different growth response under drought stress conditions (PEG 6000). Different soybean varieties significantly affected the tolerance level of PEG-induced drought stress. The addition of PEG of -0.19 MPa was able to inhibit the germination percentage and growth rate of soybean plants such as root length, shoot length, root wet weight, dry root weight, fresh shoot weight, dry shoot weight, root shoot ratio, and chlorophyll index. This is in line with Ali *et al*. (2011), drought stress at the seed germination stage reduced growth variables such as root length, shoot length, root wet weight, dry root weight, fresh shoot weight, and dry shoot weight in sorghum plants. The highest decrease in seed germination stage and growth properties was recorded with PEG below -1.2 MPa osmotic potential level when compared with control treatments on pearl millet and wheat (Gasˇparovič K *et al*., 2021). The seed germination stage is the most crucial transitional growth stage for plants, from seed to seedling, where environmental conditions of growth and development have an essential role in the success rate of growth, especially the availability of water (Rauf *et al*., 2007; Bayoumi *et al*., 2008). The effect of drought stress on seed germination and seedling stages in plants has been widely carried out, such as in wheat (Berg *et al*., 2014), maize (Farsiani and Ghobadi, 2009), and barley (Yassin *et al*., 2019).

Plant growth at the seed germination stage control by several enzymes needed by plants to obtain food reserves for embryonic development. An increase in negative osmotic potential can interfere with enzyme activity in plants, so seeds will lose their germination potential (Billah *et al*., 2021). The leading causes of decreased seed germination percentage were low water imbibition and insufficient seed moisture for germination. The decrease in seed germination percentage under negative osmotic potential (-0.19 MPa and -0.67 MPa) in this study was related to low water imbibition, thereby inhibiting the activity of enzymes required for seed germination. The test of six soybean varieties against drought stress showed a significant effect, where the Gepak Kuning variety had better tolerance to drought stress (-0.19 MPa and -0.67 MPa) when compared to the other five soybean varieties at both the seed germination and seedling stages (Tables 1, 3, and 5). This is because each variety can respond and adapt differently in the face of drought stress. The ability causes Farooq *et al*. (2020), the difference between varieties and genetic makeup of plants, to absorb moisture needed for seed germination growth.

The results of this study showed that there was an interaction between soybean varieties and potential osmotic pressure (drought stress induced by PEG) on all growth variables such as root length, shoot length, fresh root weight, dry root weight, fresh shoot weight, and dry shoot weight (Table 5, Figures 1 and 2). The highest decrease in root length (RL) was in the Dena 2 variety, which was 62.28% (-0.19 MPa) and 78.92% (-0.67 MPa) (Figure 1). In addition to root length, the highest reduction in shoot length (SL) was also in the Dena 2 variety, namely 53.23% (-0.19 MPa) and 75.38% (-0.67 MPa) (Figure 2). This is in line with the research of Bibi *et al*. (2010) and Ali *et al*. (2011), who suggested that drought stress at the seedling stage of sorghum plants can reduce plant growth characteristics such as root length, shoot length, fresh root weight, dry root weight, fresh shoot weight and shoot dry weight. This is because, at the nursery stage, roots are the first plant organs to respond to drought stress, so when experiencing drought stress, root cell division and enlargement are limited, which results in stunted root growth (Khodarampour, 2011; Rajendran *et al*., 2011). The decline in growth properties at the nursery stage due to drought stress caused by the low availability of moisture and inhibited transport of photosynthesis, where each plant genotype will respond differently to abiotic stress, which influences by the genetic composition of each genotype (Butt *et al*., 2021; Ibrahimova *et al*., 2021).

Previous studies by Dabin *et al*. (2015) and Lian *et al*. (2020) reported that water deficit conditions would result in stunted growth of root length, shoot length, root weight, shoot weight, and seed weight of 100 grains in wheat plants. Also added by Önen *et al*. (2018), the root-shoot ratio decreased along with the increase in potential osmotic pressure (drought stress). This is due to the low availability of water. In addition to root length and crown length, the chlorophyll index decreased with increasing drought stress (Jain *et al*., 2010; Farooq *et al*., 2018), similar to this study's results. Plant growth at the seed germination stage control by several enzymes needed by plants to obtain food reserves for embryonic development. An increase in negative osmotic potential can interfere with enzyme activity in plants, so seeds will lose their germination potential (Billah *et al*., 2021). The leading causes of decreased seed germination percentage were low water imbibition and insufficient seed moisture for germination. The decrease in seed germination percentage under negative osmotic potential (-0.19 MPa and -0.67 Mpa) in this study was related to low water imbibition, thereby inhibiting the activity of enzymes required for seed germination. The test of six soybean varieties against drought stress showed a significant effect, where the Gepak Kuning variety had better tolerance to drought stress (-0.19 MPa and -0.67 MPa) when compared to the other five soybean varieties at both the seed germination and seedling stages (Tables 1, 3, and 5). This is because each variety can respond and adapt differently in the face of drought stress. The ability causes Farooq *et al*. (2020), the difference between varieties and genetic makeup of plants, to absorb moisture needed for seed germination growth.

## Acknowledgements

This research was funded by the PNBP of the Faculty of Agriculture, University of Bengkulu (UNIB) 2021 No. 5895/UN30.11/LT/2021.

## References

Ali, Q., Ahsan, M., Hussain, B., Elahi, M., Khan, N. H., Ali, F., Elahi, F., Shahbaz, M., Ejaz, M. and Naees, M. (2011). Genetic evaluation of maize (*Zea mays* L.) accessions under drought stress. Int. Res. J. Microbiol, 2:437-441.

Bayoumi, T. Y., Eid, M. H. and Metwali, E. M. (2008). Application of physiological and biochemical indices as a screening technique for drought tolerance in wheat genotypes. frican Journal of Biotechnology, 7:2341-2352. https:// doi.org/10.5897/AJB2008.000–5059.

Berg, A., Karna, N. and Fuentealba, C. (2014). Energetic viability of wheat straw fractionation by acetosolv process. Cellulose Chemistry and Technology, 48:787-792.

Billah, M., Aktar, S., Brestic, M., Zivcak, M., Khaldun, A. B. M., Uddin, M. *et al.* (2021). Progressive genomic approaches to explore drought-and salt-induced oxidative stress responses in plants under changing climate. Plants, 10:1910. https://doi.org/10.3390/plants10091910 PMID: 3457944.

Butt, M., Sattar, A., Abbas, T., Hussain, R., Ijaz, M., Sher, A. *et al.* (2021). Morpho-physiological and biochemical attributes of Chili (*Capsicum annum* L.) genotypes grown under varying salinity levels. PLoS One, 16:e0257893. https://doi.org/10.1371/journal.pone.0257893 PMID: 34735478

Central Statistics Agency [BPS] (2016). Produksi luas panen dan Produktivitas Palawija di Indonesia. Retried from www.bps.go.id.

Chloupek, O., Dosta, ´l. V., Středa, T., Psota, V. and Dvořa-´čkova,´O. (2010). Drought tolerance of barley varieties in relation to their root system size. Plant Breeding, 129:630-636. https://doi.org/10.1111/j.1439-0523. 2010.01801.x .

Dabin, Z., Pengwei, Y., Na, Z., Zheng, W., Changwei, Y., Qunhu, C. *et al*. (2015). Responses of winter wheat production to green manure and nitrogen fertilizer on the Loess Plateau. Agronomy Journal, 107:361-374.

Ehdaie, B., Layne, A. P. and Waines, J. G. (2012). Root system plasticity to drought influences grain yield in bread wheat. Euphytica, 186:219-232.

Endriani, Ghulamahdi, M. And Sulistyono, E. (2017). Pertumbuhan dan Hasil kedelai di lahan rawa lebak dengan aplikasi pupuk hayati dan kimia. Journal of Agronomy, 45:263-270.

Farooq, M., Hussain, M., Usman, M., Farooq, S., Alghamdi, S. S. and Siddique, K. H. M. (2018). Impact of abiotic stresses on grain composition and quality in food legumes. Journal of Agricultural and Food Chemistry, 66:8887–8897. https://doi. org/10.1021/acs.jafc.8b02924 PMID: 30075073

Farooq, S., Onen, H., Ozaslan, C., Baskin, C. C. and Gunal, H. (2019). Seed germination niche for common ragweed (*Ambrosia artemisiifolia* L.) populations naturalized in Turkey. The South African Journal of Botany, 123:361-371.

Farooq, M., Hussain, M., Habib, M. M., Khan, M. S., Ahmad, I., Farooq, S. *et al*. (2020). Influence of seed priming techniques on grain yield and economic returns of bread wheat planted at different spacings. Crop and Pasture Science, 71:725-738.

Farsiani, A. and Ghobadi, M. E. (2009). Effects of PEG and NaCl stress on two cultivars of corn (*Zea mays* L.) at germination and early seedling stages. World Academy of Science, Engineering and Technology, 57: 382-385.

Gasˇparovič, K., Zˇivča´k, M., Brestič, M. and Hauptvogel, P. (2021). Diversity of leaf cuticular transpiration and growth traits in field-grown wheat and aegilops genetic resources. Agronomy, 11:522.

Hemon, A. F. and Sudarsono. (2010). Evaluation of somaclones peanut plants regenerated from repeat cycles of in vitro selection against drought stress. Agronomy Journal, 38:36-42.

Hubbard, M., Germida, J. and Vujanovic, V. (2012). Fungal endophytes improve wheat seed germination under heat and drought stress. Botany, 90:137-149. https://doi.org/10.1139/B11-091

Ibrahimova, U., Zivcak, M., Gasparovic, K., Rastogi, A., Allakhverdiev, S. I., Yang, X. *et al.* (2021). Electron and proton transport in wheat exposed to salt stress: is the increase of the thylakoid membrane proton conductivity responsible for decreasing the photosynthetic activity in sensitive genotypes? Photosynthesis Research, 1-17. https://doi.org/10.1007/s11120-021-00853-z PMID: 34125427

Jain, M., Tiwary, S. and Plant, R. G. (2010). Sorbitol-induced changes in various growth and biochemici parameters in maize. Plant, Soil and Environment, 56:263-267.

Kalefetoglu, T. and Ekmekçi, Y. (2005). The effect of drought on plants and tolerance mechanisms [review]. G.U. Journal of Science, 18:723-740.

Khajeh-Hosseini, M., Powell, A. A. and Bingham, I. J. (2003). The interaction between salinity stress and seed vigour during germination of soyabean seeds. Seed Science and Technology. 31:715-725.

Khodarahmpour, Z. (2011). Effect of drought stress induced by polyethylene glycol (PEG) on germination indices in corn (*Zea mays* L.) hybrids. Afr. J. Biotechnol, 10:18222-18227.

Kosmiatin, M., Hutami, S., Husni, A. and Mariska, I. (2005). Penapisan cepat toleransi terhadap kekeringan secara in vitro. Penelitian Pertanian Tanaman Pangan, 24:159-167.

Kusvuran, S. (2012). Influence of drought stress on growth, ion accumulation and anti-oxidative enzymes in okra genotypes. International Journal of Agriculture and Biology, 14:401-406.

Lian, H., Qin, C., He, Z., Niu, J., Zhang, C., Sang, T. *et al.* (2020). A synergistic increase in water and nitrogen use efficiencies in winter wheat cultivars released between the 1940s and the 2010s for cultivation in the drylands of the Shaanxi Province in China. Agricultural Water Management, 240:106308.

Mérida-García, R., Liu, G., He, S., Gonzalez-Dugo, V., Dorado, G., Gálvez, S. *et al*. (2019). Genetic dissection of agronomic and quality traits based on association mapping and genomic selection approaches in durum wheat grown in Southern Spain. PLoS One, 14:1-24. https://doi.org/10.1371/journal.pone. 0211718 PMID: 30811415.

Öhen, H., Farooq, S., Tad, S., Özaslan, C., Gunal, H. and Chauhan, B. S. (2018). The influence of environmental factors on germination of Burcucumber (*Sicyos angulatus*) seeds: Implications for range expansion and management. Weed Science, 66:494-501.

Pereira, M. J., Pfahler, P. L., Barnett, R. D., Blount, A. R., Wofford, D. S. and Littell, R. C. (2002). Coleoptile length of dwarf wheat isolines: Gibberellic acid, temperature, and cultivar interactions. Crop Science, 42:1483-1487.

Rajendran, R. A., A. R. Muthiah, A. Manickam, P. Shanmugasundaram and A. John Joel (2011). Indices of drought tolerance in sorghum (Sorghum bicolor L. Moench) genotypes at early stages of plant growth. Res. J. Agric. & Biol. Sci. 7:42-46.

Rauf, M., Munir, M., Ul Hassan, M., Ahmad, M. and Afzal, M. (2007). Performance of wheat genotypes under osmotic stress at germination and early seedling growth stage. African Journal of Biotechnology, 6: 971-975. https:// doi.org/10.5897/AJB2007.000-2119.

Richard, C. A. I., Hickey, L. T., Fletcher, S., Jennings, R., Chenu, K. and Christopher, J. T. (2015). High-throughput phenotyping of seminal root traits in wheat. Plant Methods, 11. https://doi.org/10.1186/s13007-015-0055-9 PMID: 25750658

Sugihono, C. (2011). Penapisan varietas kedelai toleran kekeringan pada fase perkecambahan dan kemampuan simbiosisnya dengan rhizobium. [Thesis]. Bogor: Graduate School, IPB University.

Widoretno, W. (2011). Skrining untuk toleransi terhadap stres kekeringan pada 36 varietas kedelai pada fase perkecambahan. Berkala Penelitian Hayati, 16:133-142.

Yassin, M., El Sabagh, A., Mekawy, AMM., Islam, MS., Hossain, A., Barutcular, C. *et al*. (2019). Comparative performance of two bread wheat (*Triticum aestivum* L.) genotypes under salinity stress. Applied Ecology and Environmental Research, 17:5029-5041.

(Received: 10 October 2022, accepted: 17 June 2023)